Challenges Encountered by Elementary Education Major Students When Learning Engineering

Devayan Bir
Department of Aerospace Engineering
Iowa State University
Ames, USA
ddbir@iastate.edu

Dagney Paskach
Grace Wilkins
Logan Angstead
Kelvin Miskowiec
Hubert Ooi
College of Engineering
Iowa State University
Ames, USA

Benjamin Ahn
Department of Aerospace Engineering
Iowa Sate University
Ames, USA
bahn@iastate.edu

***Abstract*— It is essential that elementary students are exposed to engineering at an early age to help build a base of knowledge on which to expand later in their schooling. With the world constantly advancing in terms of technology, elementary education (ELED) teachers are not well equipped to teach engineering to elementary students. With this in mind, for the past two decades Iowa State University has offered a course, Toying with Technology (TwT), for ELED majors, which addresses the issue at hand. The course not only teaches basic engineering through hands-on activities but also trains the students in building engineering lesson plans and teaching them to elementary students. This study gathered qualitative data by conducting focus group interviews with the students (*N* = 30) enrolled in the TwT course. Inferences made from the qualitative analysis will help in understanding the impact of the class on ELED students and their challenges. Modifications to the TwT course will be proposed so that future ELED students can be better taught these concepts and be comfortable teaching them to elementary students.**

Keywords— Teacher education; Technology knowledge; Teaching skills; K-12 preparation

I. INTRODUCTION

To inspire the minds of elementary students in the field of engineering, it is important that future elementary education (ELED) teachers know how to teach engineering topics in a manner that broaden the horizons of elementary students. With such responsibilities, it is crucial that ELED major students are equipped with the necessary concepts and pedagogical techniques to teach elementary students. Toying with Technology (TwT) is a course designed using constructivist theory where ELED major students are introduced to technical concepts by completing engineering projects (e.g., designing, building, and testing egg drop machines and making boats, Lego robots, and Rube Goldberg contraptions) in groups of two. These projects are designed for a "hands-on" approach to learn basic principles of engineering and technology. The ELED students also have to develop engineering lesson plans that will be taught by them at a local elementary school. TwT is a required course for ELED students pursuing a technology elective as a part of their undergraduate degree.

The goal of this study is to improve the TwT course so that the ELED students can be exposed to engineering and technology in a manner that prepares them to teach engineering to elementary school students. Literature offers very limited number of studies that look at the various challenges and experiences ELED students face when grasping the concepts of engineering. In an effort to introduce and teach engineering concepts to ELED students, studies are needed that identify challenges encountered and experienced by them. This study will help to select better content to design the course and to improve learning in ELED students. This study addresses the above need by answering the research question:

- What are the challenges encountered by ELED students while learning about engineering in the TwT course?

This study gathered qualitative data by conducting focus group interviews of the students (*N* = 30) enrolled in the TwT course. Pre-interviews were conducted at the beginning of the semester with the focus groups to find the challenges students foresaw and what they expected to learn from the class. From the pre-interview analysis, a post-interview protocol was developed. The post-interviews will be conducted at the end of semester to see if the course helped students achieve their set goals and overcome the challenges.

Inferences made from the qualitative analysis will help understand the impact of the class on the ELED students and their challenges. Modifications to the TwT course will be proposed so that future ELED students can be better taught these concepts and be comfortable teaching them to ELED students. The study is expected to help the engineering education community understand how future elementary school teachers should be exposed to the field of engineering so that they may pass their knowledge on to their future school students.

II. LITERATURE REVIEW

A. Concerns with STEM Education in K-12

Students in elementary school are greatly influenced by their teachers when learning science, technology, engineering and mathematics (STEM) [1]. This is one of the prime reasons why STEM education is introduced to students in elementary schools [2]. Preservice teachers go on to teach elementary school in the same manner they were taught in K-12 schooling [3, 5]. This makes introduction to STEM during preservice teacher training crucial, but only 30% of elementary education

978-1-5090-5920-1/17/$31.00 ©2017 IEEE

programs require students to take a course that gives them the required background in STEM [4]. Only one-third of the preservice teachers receive adequate education to teach STEM topics; thus, most ELED teachers are not prepared to teach such topics. It is likely that they will teach STEM in a traditional lecture based method [5] or even teach with the use of unreliable techniques and sources [7, 8]. A study [6], which surveyed 98 elementary education teachers in the state of Arizona, reported that all of the survey participants had an inadequate knowledge about design engineering and technology (DET). The study also found that elementary education teachers had a stereotypical view of engineers as having poor writing, verbal, and people skills. With such a narrow perspective about engineers, these teachers would not be able to provide an overall picture or even an adequate portrayal of engineering. In an effort to improve the preservice teacher training for effective STEM education, the National Research Council and the National Academics of Engineering have stressed the need to change the present teaching style and teacher preparation in elementary STEM education [9, 10, 11]. There is a need for effective STEM education in preservice teacher training [12, 13]. With the increasing demand for teachers who are adequately trained to teach STEM concepts to elementary students, the aim of the study is to identify the challenges that ELED majors encounter.

B. *Effective Elementary Education Teacher Training*

With effective ELED teacher training as a goal, the study [6] suggests a course that uses simple technologies to teach preservice teacher the importance of engineering. It predicts that preservice teachers will face issues creating lesson plans that infuse STEM concepts. It also emphasizes that the stereotypical views of engineering among elementary teachers should be addressed in preservice teacher training.

A recent article [14] researched a course that used robotics to promote STEM engagement in preservice teachers. The study employed mixed methods on data collected from surveys, classroom observations, interviews, and lesson plans of preservice teachers enrolled for an introductory STEM course. The study reported that the STEM engagement of the pre-service teachers improved significantly with the use of hands-on instructional approaches such as robotics. The study shows that due to lack of prior knowledge, students initially reported frustration and lower confidence in robotics activity. After course completion, the students' negative attitudes transitioned to feelings of enjoyment and motivation towards STEM related topics and coursework. The preservice teachers also showed improvement in lesson planning and teaching STEM. The study suggests that the outcome of STEM teaching should be measured from the participants actual teaching of lesson plans rather than from just the lesson plans.

A study [15] survey that analyzed preservice teacher expectations in an introductory engineering course for K-12 preservice teachers reported that all participants benefited from exposure to the engineering design process, developing lesson plans, and learning about resources to teach STEM concepts to their future elementary students. The participants expressed the importance of hands-on learning when teaching STEM concepts and would use the various hands-on learning techniques to teach their students. The course had instilled creative methods in the participants to teach elementary school students. It concluded that innovative techniques should be derived from the survey results to teach preservice students at an undergraduate level.

This study will add to the literature, which supports a course design that incorporates hands on learning, lesson planning, and teaching preparation to effectively train ELED students to teach STEM concepts to elementary students. It will also provide useful insights into developing a framework for preservice teacher preparation.

III. Research Design

A. *Settings and Participants*

The research was conducted at Iowa State University and the research participants were ELED majors who had enrolled in the TwT course in the spring semester of 2017. The TwT is a required course for ELED students who are pursuing a technology elective. The spring 2017 cohort consisted of 30 students (25 females, 5 males) who were interviewed as focus groups and were given an incentive of 10 points out of a total of 660 each to attend the interview sessions. These interview sessions were conducted during specified class hours so that students did not have to spend additional time to attend these sessions. This also ensured that all students attended the focus group unless they were absent from class on the scheduled day. Absentees were allowed individual interviews at a later time allotted by the investigators of the study.

B. *Methodology*

The case study methodology was used to explore the research question. This method was chosen because it is well suited to study "specific, unique bounded systems" [16], specifically in this case, a required course for elementary education majors, which introduces engineering concepts. The study is bounded in the sense that it is applicable only to elementary education majors who are interested in teaching engineering to K-12 students. Case study in the form of naturalistic generalization is well suited to explore the unique dimensions of the case while being able to generalize its findings to other individuals [17]. The goal of this research is to find the challenges faced by these students and suggest improvements applicable to future cohorts of the course.

The first phase in the research design used the conceptual framework of experiential knowledge. The first step was to discuss with the course professor his experiences in teaching ELED students for the past 20 years. The purpose was to determine the capabilities of the students enrolled for the course to learn engineering. The next step in the research design was to meet with teaching assistants who had previously taken the same TwT course. The purpose here was to find out how the course helps students and what issues they face while learning engineering. From the discussions with faculty and the teaching assistants of the course it was concluded that the objectives of the course were to introduce the students to programming, design, math, and engineering so

that they would be confident in teaching these topics. Informed consent from the participants was obtained on the first day of the course.

Subsequently, discussion sessions were held which involved five undergraduate researchers and the principal investigators (PI) of the study. A research protocol was then developed for the focus group interviews conducted by the undergraduate researchers who, to provide them with experience and confidence to conduct the main interviews, had first conducted pilot interviews with groups consisting of the TwT course teaching assistants.

There were six TwT students in each of the five focus groups with each group interviewed by an undergraduate researcher. These pre-interviews were recorded by audio recorders so that they could be transcribed. Before conducting the interviews, the research participants were introduced to the research study and were told that their responses would be kept anonymous so that they could answer the interview questions without any hesitation. The pre-interviews were conducted during the third week of the course in a 15-week semester. On an average, each interview lasted for 18 minutes.

C. Data Analysis

Immediately after the pre-interviews, the undergraduate researchers were to complete a contact sheet describing their experiences and noting anything unexpected that might have caught their eye while conducting the pre-interviews. Subsequently, the interviews were transcribed by the undergraduate researchers who had learned how to transcribe interviews and been provided with example transcripts so that they would transcribe the recordings similarly. Each undergraduate researcher transcribed their own interviews verbatim from the audio recordings made during the interviews. Sessions headed by the PI were conducted with the undergraduate researchers to develop themes for all the questions pertaining to each interview.

The first step in data analysis was to categorize responses from each transcript. From these response categories, themes were developed for each question such that all the responses would fit into at least one of the themes. The themes were then defined, and a codebook was created. Reliability tests were conducted by asking each of the researchers to code all the responses from each transcript. The response codes from each researcher were then compared.

Discrepancies between the response codes were deliberated until the research team reached a unanimous decision either with the response and its corresponding theme or the theme definition itself. When the discrepancies involved the response code of one or more of the researchers, the researchers were given the responsibility to explain their stance on the particular response to the research team. All such discrepancies usually occurred because the researcher had not clearly articulated the theme definition. The theme definitions were then clarified and restated such that there was no more confusion regarding a definition. In other cases where the discrepancy could not be resolved or agreed upon, new theme categories were created, keeping in mind the research question. This process was repeated until all the researchers agreed on the responses and their corresponding themes.

IV. Results

A. Challenge 1: Background in Engineering

Although highly motivated to teach, most students had only a very general understanding of what engineering was. A typical response to what engineering meant was *"Science"* or *"building stuff."* Some responses involved being creative and solving problems, but they were no more than one-word answers. None of the responses provided a complete definition or even some insights into engineering. The TwT students expected to learn basic engineering concepts through the course. A typical response was *"I'm sure by the time we're teaching there's going to be so much more engineering in the classrooms that we're going to really need to know how to do at least the basic stuff, so I want to learn the basics."* They also wanted to get acquainted with the pedagogical techniques used to teach children and to design lesson plans to teach engineering to children. They wanted to learn the concepts not only to grasp them themselves but also to be able to teach them to children in an age appropriate manner. They wanted to know how to incorporate this engineering element into their own lesson plans. A student responded *"I think like more age appropriate things they can do depending on what grade level you are in. You will know more age appropriate like type of activities for each subject."* The students also expressed their lack of experience with STEM education. An example response was *"I guess help kids to be more aware what engineering is and I guess the basics of it because I don't think I ever did much with the basics of engineering."*

B. Challenge 2: Teaching Engineering to Elementary Students

Overwhelmingly, the students thought their biggest challenge would be to understand engineering concepts and to teach them to their future students. One student responded, *"The biggest challenge would be the fact that I have not really dealt with any of this type of stuff before as far as the robotics and as far as some of the creating things, we have to do. It is fun, but definitely is something we haven't been shown or done before."* Overall, the majority of the responses suggested that the students were not confident in teaching engineering to students. A key point to note here is that a lot of students said that they felt confident in teaching as long as they were provided with resources. These resources include lesson plans or tools to help them teach the lesson plans.

It was expected that the students of TwT were not comfortable with engineering concepts since that is the reason they had enrolled for the course. Once the data was analyzed, it showed that these students were neither comfortable with engineering concepts nor had been exposed to it prior to the class except for some basic programming.

C. Challenge 3: Understanding Engineering Concepts

Most responses from the focus group interviews revealed that the TwT students did not have an understanding of design or computer aided modeling. A few students recognized it

because they had either come across it at their work place or took a class in high school. A student responded, *"…we did like a lot with like wheels or just houses or just like simple things that you can like draw out, so we drew them out on paper, and then we like moved to the computers for the rest of the class, and it's just using like a computer program to draw everything out and make like blueprints basically."* The TwT students had to take a prior course, which taught them block-based programming, and so most responses mentioned or recognized programming. Apart from this the students did not have much knowledge about its uses and application. A typical response was *"We did scratch so like we programmed a very basic game."* Many of the responses about problem solving involved the use of the trial and error approach. Typically, students responded *"Keep bashing our heads against the wall until it works and usually it works."* Other responses were related to asking for help from the TAs. A few students responded with a systematic approach and creative thinking. A student responded *"Problem solving skills I think like first of all you need to define like what your problem is. And then go at it with um like what are different… and then like what you want your end solution to be."*

D. Challenge 4: Negative Attitudes towards Engineering

Apart from the lack of understanding about engineering, the students of TwT carried negative attitudes towards engineering coming into the course. When asked what engineering meant to them, the TwT students replied with very basic words to describe it and described their personal feelings towards engineering. The TwT students were under the notion that engineering is intimidating and a lot of work. Some typical responses were *"intimidating," "lot of work," "challenging," "it's hard."* Apart from saying that engineering is a hard program, some students said that his/her family thought that engineering is a tougher field to study.

V. Discussion

The ELED majors enrolled in the course to get an introduction to engineering, so it was expected that these students would grapple with the hands-on activities that require basic engineering principles to solve and complete. The students were also unfamiliar with the basic components of engineering--design, programming, and building. The above challenges show that the students had not been exposed to engineering and its applications. With little background in STEM topics and its applications, most of the students also expressed low confidence in teaching these topics to elementary students. The TwT course was designed with a hands-on approach to engineering. A hands-on approach includes activities such as designing, building, and testing egg drop machines, boats, Lego robots, and Rube Goldberg contraptions. The goal of these activities is to expose the ELED majors to the engineering process and improve their confidence in approaching STEM topics. These hand-on activities are taught in modules that involve the use of one or more of the basic engineering components. For example, the Lego robot module requires the students to use text-based programming to control the movements of the Legos. In this way, the students experience the application of engineering through these modules. The hands-on activities the ELED majors have to work with are also found in elementary classrooms and are directly translatable to lesson plans for their future students. The TwT course requires the ELED majors to conduct eight "Classroom Experience" sessions. In these sessions, the ELED majors are paired with two elementary school students from a nearby school. Each ELED major has to develop and teach an engineering lesson plan to their elementary students. This gives the ELED majors a chance to interact with their future students and practice teaching the engineering lesson plans they developed.

The larger challenge for these ELED majors will be to overcome their negative attitudes towards engineering. The ELED majors must get over their fear or feeling of intimidation towards engineering topics. They must learn to see engineering in a new light and see its application in their day to day lives. They must realize the importance of engineering and technology in the present and future in order to inspire the minds of their future elementary students. The ELED majors must acknowledge that engineering is important to teach to elementary students and use innovative pedagogical techniques to teach it. The TwT course was designed to address the challenges faced by the ELED majors through the various course modules and its hands-on approach. To see the impact the course had on the ELED majors regarding engineering, a post-interview will be conducted to see if the students' content knowledge of engineering and its various components have changed. The post-interviews will also show if the TwT course had an impact on their confidence in teaching STEM topics. The goal is to see if the challenges that the students faced prior to the course are being addressed and see if modifications or additions can be made to the TwT curriculum to improve student learning.

VI. Conclusions

The focus group interviews allowed for deeper insights into the challenges ELED majors face while learning STEM topics. The study implications will provide important guidance in developing a framework for preservice teacher preparation in effective STEM education. The future steps in the study will be to analyze the post- interviews to see if the TwT course had an impact on students' knowledge about engineering and their confidence in teaching it to elementary students. The analysis of the post-interviews will show if the TwT addressed the challenges the ELED majors face while grappling with STEM topics. The research questions the analysis will help answer are (1) How did the TwT course influence the ELED students? (2) What modifications can be made to the TwT course so that it improves the understanding of engineering among ELED students?

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